Key buffering factors of aerosol-indirect effects: Their physical understanding and parameterization in climate models

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Despite progress in understanding of aerosol-cloud interactions and their representation in climate models, climate models still suffer from large uncertainty in estimated aerosol indirect effects and large discrepancy compared to observations. It has been increasingly recognized that the vexing problems are likely related to the factors that compensate or buffer aerosol-cloud interactions as conventionally represented in climate models. This study will review and report our research on four potentially important but poorly understood such buffering factors in warm clouds: 1) non-linear dependence of cloud properties on aerosol concentration and updraft velocity; 2) dispersion effect associated with the aerosol-induced changes of the spectral shape of the cloud droplet size distribution; 3) effect of entrainment-mixing processes, 4) subscale-variability, 5) "secondary" aerosol factors (hygroscopicity, mean size and spectral shape. The relationships between aerosol properties, vertical velocity, cloud properties and entrainment rate will be explored in the context of considering clouds as an open system. New regime equation will be presented that can be used to quantitatively separate aerosol-limited regime from the regime limited by vertical velocity. Future direction will be discussed as well.